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Ecological and biological features of the selected forms of checker tree for successful targeted introduction and reintroduction into the ecological network of Ukraine

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Abstract. The study considers the issues of introduction and reintroduction of the Red Book species of checker tree in the system of decorative gardening, forest protection, and forest ecosystems. That is why the purpose of the study was to monitor the green corridors of rural and urban ecosystems of the forest-steppe zone of Ukraine, to investigate and select the best forms of checker tree in terms of morphological characteristics and physiological properties for promising areas of distribution and conservation in the form of pure and mixed plantings. The following methods were used in the research: route, field, biometric, laboratory, comparative analysis, mathematical and statistical. New forms of checker tree were introduced, studied in *in situ* and *ex situ* conditions, and selected for the prospects of their further introduction and reintroduction into the ecological network of Ukraine and conservation to activate trophic, phoric, and other types of biotic interactions in a single territorial ecosystem. Sparsely distributed biotypes of *Torminalis glaberrima* (Gand.) Sennikov & Kurtto f. *Intermedia* Kossetz were found in the zone of green corridors of rural and urban ecosystems of the forest-steppe zone of Ukraine. Some specimens of these biotypes were identified as valuable material for introduction into the system of fruit and ornamental gardening, including parks and monuments of landscape art, as well as natural monuments, protected tracts, sanctuaries and reserves of pure and mixed plantings, alleys, forest reclamation strips, etc. It was established that the elements of originality of the selected forms of checker tree – Eva, Podolianochka and Slavka – are the specificity of the crown shape, which determines the level of productivity, small and medium growth force, normal reaction to pruning (which affects the size and yield of fruits), high degree of flowering (60-80%), increased fruit size (diameter of more than 2 cm), increased fruit weight (1.8-2.1 g), increased number of fruits on the stem (≥ 20 units), a pleasant and harmonious taste of fruits, high quality of fruits, lack of periodicity in fruiting in nature and in culture, high xenogamy (69-75%), high yield of fruits from the plant, increased winter hardiness (7.5 pt.), high drought resistance (8 pt.) and resistance to pests, including pear leaf blister mite (7-9 pt.). The findings can be used in the future to replenish pure and mixed plantings in the ecological network of Ukraine

Keywords: *Torminalis glaberrima* (Gand.) Sennikov & Kurttof. *Intermedia* Kossetz.; biochemical properties; new biotypes; replenishment of the ecological network; Red Book species; ascorbic acid content

Introduction

Forest ecosystems, as an object of the ecological network, are considered necessary as reservoirs of biological diversity, oxygen producers, and carbon dioxide sinks. Modern threats to forest ecosystems, such as the loss of biodiversity, often disrupt their biological integrity and ecological functions. M. Breil *et al.* (2023) note that broad-leaved forests are characterised by a higher albedo, are marked by reduced stomatal resistance and greater branching of the root system, compared to coniferous forests,

in addition, deciduous forests, which include checker trees, absorb less solar radiation spectra, and therefore, the process of evaporation of accumulated water is less intense. But historically, deciduous forests were used for cutting and clearing land for agricultural purposes, and then gave way to urbanisation. As reported by H. Lundmark (2020), in Europe, forests have been used since prehistoric times for various purposes, such as forest pastures, silvicultural reclamation, and logging.

Currently, only 1% of the original forest remains in Central Europe (Sabatini *et al.*, 2021). In this regard, the introduction of endangered species stocks, which have almost no viable places for reintroduction to foreign locations, is gaining relevance. Therefore, significant progress has also been made for some ecologically threatened and endangered species, with new biotechnological advances that have made reintroduction affordable (Douglass *et al.*, 2023). However, as noted by M. Gastauer *et al.* (2021), environmental laws in many countries require the use of native species to restore destroyed land through the reintroduction of native species. As noted by C.E. Aslan (2019), alien plant species intentionally imported or distributed naturally from neighbouring areas can harm public health, biodiversity, and the overall ecosystem.

Y.A. Othman *et al.* (2023) note that the conservation of endangered plant species in their native regions is crucial. According to J.M. Werres (2018), checker tree is one of the tree species that is on the verge of extinction, which inevitably affects the normal course of biological processes, for example, plants of this species are the food base for many birds and mammals, etc. In this regard, it is necessary to monitor the biodiversity of forest ecosystems, preserve checker trees and select the most productive and ecologically adaptive specimens, whose high vitality will determine their growth and development in the forest ecosystem. It should be borne in mind that if checker trees have been eradicated from certain forest ecosystems where they previously existed, new specimens that will make up the re-introduced population should be taken from wild populations. When selecting tree specimens for reintroduction, it is important to consider local adaptation, adaptation to *ex situ* conditions, the possibility of inbreeding and outbreeding depression, and the taxonomy, ecology, and genetic diversity of the original population. Therefore, care should be

taken to avoid inbreeding and inbreeding depression. During reintroduction of species, it is proposed to cover as much genetic diversity as possible, which is measured as heterozygosity.

Plants undergoing reintroduction may show reduced fitness if they are not sufficiently adapted to local environmental conditions. In this regard, researchers should consider the ecological similarity of source and recipient sites when choosing populations for reintroduction. As noted by M. Löf *et al.* (2019), to ensure the functioning of the ecosystem in the future, checker tree recovery programmes must integrate ecological knowledge, best practices and regeneration systems, overcome biotic and abiotic disturbances, and adapt to future forest landscapes. In this regard, historically, the source of plant material for reintroduction has followed the “local is best” rule as the best way to preserve local adaptations, with specimens for reintroduction selected from the closest geographical population. For plants, minimisation of adaptation to captivity is usually achieved by obtaining plant material from a seed bank, where specimens are stored as seeds collected in the wild and have not had the opportunity to adapt to captive conditions. However, this method is only possible for plants with dormant seeds.

According to M.M. Rahman *et al.* (2018), *ex situ* conservation of endangered species of checker tree is important for sustainable use of forest genetic resources in Ukraine. N.P. Schpak *et al.* (2020) substantiated the feasibility of introducing checker tree into hornbeam, beech or oak cultures as a fitting species and as a forest soil structurer. However, the issues of targeted introduction and reintroduction to the ecological network system of Ukraine remain open. As stated By I. Robiansyah & Dodo (2022), for the successful process of reintroduction of checker tree, among other things, it is important to involve local

communities in the care or supervision of plants, and to prevent and reduce disturbances in the area of conservation activities and for the effective management of certain activities.

Reintroduction of checker tree in light broad-leaved forests and oak stands, where they fell under the influence of anthropogenic factors, contributes to the restoration and preservation of plants. This strategy may involve planting them in pristine forest ecosystems or restoring degraded ecosystems that promote long-term plant viability. An important part of this approach is to integrate management with the environment to ensure their long-term conservation.

The purpose of the study was to monitor the green zone of rural and urban ecosystems of the forest-steppe zone of Ukraine to select the best forms of checker tree in terms of morphological characteristics and physiological properties for promising areas of their introduction and reintroduction into the ecological network of Ukraine.

Materials and Methods

Stationary research was conducted on the territory of the Institute of Horticulture of the National Academy of Agrarian Sciences (NAAS) of Ukraine and its scientific network (Lviv Oblast) during 2017-2021, expeditionary research – 2015-2021 in forest parks of rural and urban ecosystems in Kamianets-Podilskyi district of Khmelnytskyi Oblast (Ukraine). The search for checker tree localities was carried out in the Kamianets-Podilskyi district (green zone of the urban ecosystem of Kamianets-Podilskyi, the outskirts of the Suprunkivtsi village).

To select the best forms of checker trees, the methodology of forestry and taxation studies by N. Anuchin and R. Anoshin was used to determine the biometric parameters of the stand. Phenological observations were performed according to N.I. Bazilevich. The flowering phase and fruiting abundance were

evaluated according to V.G. Kapper. Considerable attention was paid to the study of morphological features of the inflorescence, flower, and focused on the definition of the degree of flowering. Biometric assessments of plants included determining: height, growth strength, direction of placement of skeletal branches, position relative to the trunk and angle of their placement, crown and trunk diameter, crown density and shape, tree habitus.

At the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine and its scientific network, grafted plantations of selected checker tree forms were established (*ex situ*) and studied for biometric parameters, winter hardiness (Sokolov, 1957), and drought resistance (Pyatnitsky, 1976).

To investigate specimens of checker tree by morpho-physiological characteristics and properties, several breeding forms were selected: Eva, Podolianochka, and Slavka, the intraspecific taxon of which was *Torminalis glaberrima* (Gand.) Sennikov & Kurtto, belonging to the variety *T. glaberrima* (Gand.) Sennikov & Kurtto. f. *intermedia* Kossetz. In addition, morphological features of vegetative and generative buds, shoots, leaves (density of placement at the end of the shoot, size, intensity of green colour, cross-section profile, intensity of anthocyanin colour, glossiness, pubescence on the upper and lower sides, type and format of the apex, shape of the base and edge, type of venation, number of blades, time of onset of yellow, red leaf colour time of leaf fall), inflorescences (type, diameter, number of flowers), flowers (diameter, calyx in height, position of the stigma relative to the anthers, pedicel by length, shape of anthers, number of anthers, colour of the base of the staminate thread, colour of the underside of the petals, position of the petals, location of the petals, number of petals, colour of the anther), fruit (height, width, diameter, uniformity of ripeness, main colour of the peel,

glossiness of the peel, density of the lenticel location, weight, surface texture, aroma, shape, peduncle in length, pubescence of the peel, villi in density, colour of the villi, depth of the calyx, colour of the pulp, weight of 1,000 fruits, number of fruits on the corymb, the number of seeds in the fruit). The abundance of fruiting

was evaluated on a 6-point scale of visual yield assessment according to V.G. Kapper. Phenological observations were performed according to I. Beideman.

Drought resistance during the growing season was determined on the scale by S.S. Pyatnitsky (1976) (Table 1).

Table 1. Scale of evaluation of checker tree plants for drought resistance

Signs of drought resistance	Score
No signs of drought damage	5
Leaves lose water in the daytime, are in a state of plasmolysis, restore turgor in the dark	4
Leaves of the lower tier lose colour, dry up and fall off, but the shoots of the upper tier are characterised by normal growth and development	3
Almost all leaves dry out without changing colour, but the shoots do not lose their viability and next season resume development due to apical buds.	2
Almost all leaves and tops of annual shoots dry out without changing colour	1
Plant dies	0

Source: S.S. Pyatnitsky (1976)

The intensity of damage by pests and diseases was determined visually guided by the educational and methodological work of I.M. Mrynskyi & T.M. Tymoshchuk (2022). The analysis of the age structure of checker tree habitat areas was carried out following the generally accepted methodology and according to the recommendations of I.V. Semechkin and E.N. Ioshchenko & N.N. Lashchinsky. The degree of flowering was estimated according to O.A. Kalinichenko (2003), abundance of fruiting – according to V.G. Kapper.

Determination of taste and tasting assessment was carried out according to S.O Tkachyk (2016), Methodology for examination of fruit, berry, nut, and grape plant varieties for distinction, homogeneity, and stability (2022).

Biochemical analyses of checker tree fruits were carried out in the laboratory of selection and technology of growing berry crops and the laboratory of post-harvest quality of fruit and berry products of the Institute of Horticulture of the National Academy of Sciences and independent laboratories for assessing the quality of fruits.

The content of pectin substances was monitored according to DSTU 8069:2015 (2017), ascorbic acid – DSTU ISO 6557-2:2014 (2015). The study considered the standards of the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1979) and Convention on Biological Diversity (1992). The study data were statistically processed in the Excel-2007 software suite.

Results and Discussion

In September 2022, new forms of checker tree were included in the Genetic Bank of Ukraine based on a successful examination conducted by the National Centre for Plant Genetic Resources of Ukraine (Kharkiv). The introduced specimens were studied for morphological traits, biological properties, and economic characteristics and are stored in the collection of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (Novosilky village, Fastiv district, Kyiv Oblast) and the Podilska Rozkish fruit and berry mini-nursery (Muksha Kitaygorodska village, Kamianets-Podilskyi district, Khmelnytskyi Oblast).

The *Eva* specimen of checker tree (certificate No. 2375, National catalogue No. UN0700091) belongs to the category of wild form, discovered and selected in 2015 at the border of Suprunkivtsi village (Kamianets-Podilskyi district, Khmelnytskyi Oblast). The wild form of *Eva* is registered as a sample of the gene pool based on the following originality elements: a combination of fruit weight of 2.1 g, fruit diameter of 2.2 cm, ascorbic acid content (55 mg/100 g of raw weight), tasting score of fruits of 8 points, high winter hardiness (7 pt.), drought resistance (8 pt.), with a fruit yield of 12.5 kg/plant.

In addition, the plants of are characterised by high plasticity relative to pruning, early time of maximum fruiting in culture (at the 3rd year), a high degree of flowering – 60-80%, increased self-fertilisation – 69%.

Signs of identification of a sample of checker tree *Eva*, which determine its difference (morphological, biochemical, etc.) life form – a conical tree with a rounded crown, a high number of skeletal branches (>10) and strong branching. The angle of position of skeletal branches relative to the trunk is 45° at a height of 1.5 m (Fig. 1).



Figure 1. Plant (tree) of the wild form of *Eva* checker tree

Source: photo by the authors

Plants of the *Eva* specimen are characterised by high growth power (0.36 m/vegetation). The size of the vegetative buds is small (6 mm), the colour of the vegetative bud is dark cherry, the position of the vegetative bud relative to the shoot is slightly deviated. The time of the beginning of the development of vegetative buds is average (the end of the 3rd ten days of March – the beginning of the 1st ten days of April) and the time of flowering of vegetative buds (the appearance of leaves) is also average (the 2nd ten days of April). Annual shoot: medi-

um thickness (4.5 mm). The colour of the bark of the annual shoot is olive-grey with numerous lenticels, which give it a specific grey hue. The size of the bud base on an annual shoot is average (6 mm). The intensity of the green colour of the leaf is moderate, the size of the leaf is average (13.2×11.9 cm), the shape is pointed-ovate lobed and dissected, the leaf type is simple, and the type of its tip is pointed and drawn, the shape of the base is slightly truncated or notched, the shape of the edge is biserrate, the length of the petiole is medium (4 cm), the

pubescence on the upper side of the leaf is absent, the lower side is absent or weak, the number of blades on the leaf is 7. The density of leaf placement at the top of the shoot is average

(4 units). It was found that the time of the onset of yellow leaf colour is average (the end of the 2nd – beginning of the 3rd ten days of September) and the time of leaf fall is also average (Fig. 2).

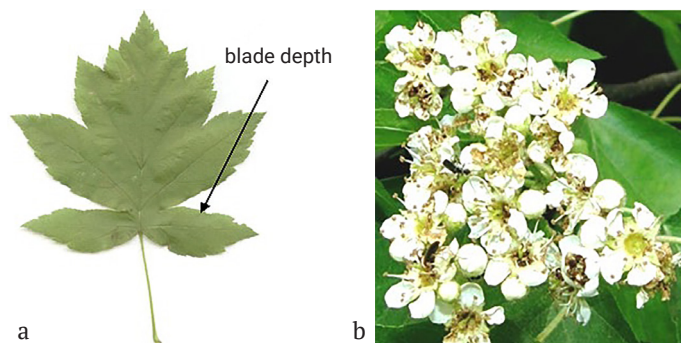


Figure 2. Leaf (a) and inflorescence (b) of checker tree form Eva

Source: photo by the authors

The inflorescence of Eva checker tree is a medium-sized corymb (average diameter – 18 cm), the flower is medium in diameter ($d=1.6$ cm), five – petalled, the perianth petals are white, intersecting, placed horizontally (Fig. 2). Placement of the flower stigma relative to the anthers is lower. The number of stamens is 20. The colour of the anthers is dark yellow or yellow and orange. Pedicel pubescence is weak. The number of flowers on the corymb is average (48). The fruit of the plants is an apple, with a large diameter ($d=2.2$ cm). It should be noted that the time of the beginning of flowering is average (the beginning of the 2nd ten days of May). The degree (signs) of flowering is a maximum of 4 points, or 60-80%, which is very good in rank. The self-fertilisation rate of Eva plants is high (69%). The ripeness group of the Eva sample is average. The time of the beginning of maturation depends on weather conditions and may fall at the end of the 3rd ten days of August, and the 1st ten days of September or the 2nd ten days of October. A similar dependence is observed with regard to the onset of the phases

of vegetative buds, budding and flowering, etc. Morphological characteristics of the fruit are as follows: the fruit is tall (2.3 cm), medium in width (2.5 cm), medium weight (2.1 g), colour – light brown, pulp colour – brown, shape – elliptical or broadly oval, peduncle is long (5.5 cm), depth of the calyx – closed, lenticels are located on the skin tightly, the texture of the skin surface is smooth or slightly rustling, the skin pubescence is weak, the colour of the pubescence (villi) is white (Fig. 3).



Figure 3. Checker tree fruits of the Eva form
Source: photo by the authors

The taste of the fruit is moderately sweet with a slight sourness, fruity with hints of dried apricots. The tasting rating of fruits is high (8 points). The number of seeds in the fruit is small (0-3 units). The seed colour is light chestnut or brown. Uniformity of fruit ripening: uniform (in culture) and not uniform (in nature). The number of fruits on the corymb is average (19). The abundance of fruiting of plants is average or good – 3.5 points. It is established that the time (age) of the onset of maximum fruiting from the seedling is late (8 or more years), but the time (age) of the onset of maximum fruiting on the scion is early and is 2-3 years. It was found that checker tree plants are very plastic and in culture, subject to the observance of care systems, are able to form a high fruit yield at the age of 10-15 years, exceeding 10 kg/plant. For wild-type Eva plants, the average fruit yield at the age of 29 is about 12.5 kg/plant. The fruiting cycle is periodic.

The Podolianochka specimen of checker tree (certificate No. 2377, National catalogue No. UN0700092) belongs to the category of wild form, discovered and selected in 2015 in the park area of Kamianets-Podilskyi, Khmelnytskyi Oblast. The wild form of Podolianochka was registered as a sample of the gene pool based on the following elements of originality: a combination of fruit weight of 1.9 g, a high number of fruits per stem – more than 20 units, drought resistance of 8 points, resistance to pear leaf blister mite of 9 points, with a fruit harvest of more than 10 kg from a plant at the age of 10 years. Pleasant harmonious taste of fruits. Cup-shaped crown, low growth force (0.25 m/vegetation), good reaction to pruning, no periodicity in fruiting in nature and culture, self-fertility – 75%.

Signs of identification of the wild form Podolianochka, which determine its difference: life form – a tree that ranges in habitus from straight to sprawling, the crown shape is transversely elliptical, a high number of

skeletal branches (>10), strong branching, the angle of position of skeletal branches relative to the trunk is 55° at a height of 1.5 m (Fig. 4).



Figure 4. Plant (tree) of the wild form of Podolianochka checker tree

Source: photo by the authors

Plants of Podolianochka form are characterised by a small size of vegetative bud (6 mm), the colour of vegetative bud is dark cherry, the shape of vegetative bud is blunt ovate, the position of vegetative bud relative to the shoot is slightly deviated, the intensity of green leaf colour is moderate, the leaf size is average, the leaf type is simple, the leaf shape is pointed-ovate dissected, leaf petiole length is average (4 cm), the inflorescence is a medium-sized corymb, with a diameter of 17 cm, flower in diameter – medium, perianth petals – white, intersecting, horizontally arranged, number of flowers in inflorescence – medium (45 units). Morphological features of fruits: medium diameter ($d=1.7$ cm), medium weight (1.8 g), shape – elliptical, or broadly oval, peduncle is long (5 cm), calyx is shallow (≥ 1 mm), colour – light brown, pulp colour – brown, seed colour – light chestnut or brown (Fig. 5).



Figure 5. Leaves and fruits of the wild form of Podolianochka checker tree

Source: photo by the authors

The taste of the fruit is moderately sweet with a slight sourness, fruity with hints of dried apricots, excellent aftertaste of dried fruits. It is also worth noting that the number of fruits on the corymb is average (11). The time of the beginning of ripening of fruits in the wild state is average (1st ten days of September), in culture on a scion – early (on 2nd-3rd years). The abundance of fruiting is average and is 3.5 points (average or good harvest). The average fruit yield at the age of 30 years is 10.6 kg/plant. The ripeness group is average.

The Slavka specimen of checker tree (certificate No. 2376, National catalogue No. UN0700090) belongs to the category of wild form, discovered and selected in 2015 in the park area of Kamianets-Podilskyi, Khmelnytskyi Oblast. The wild form of Slavka is registered as a sample of the gene pool based on the following elements of originality: the specificity of the crown shape (cup-shaped), which determines the level of productivity, low growth force (0.25 m/vegetation, good reaction to pruning (which affects the size and yield of fruits), increased fruit weight (1.9 g), high number of fruits on the stem (≥ 20), pleasant harmonious taste of fruits, lack of periodicity in fruiting in nature and in culture, high self-fertility (75%), increased yield of fruits from the plant

(>15 kg/plant), by year (5 t/ha), increased winter hardiness (2 pt.), high drought resistance (4.5 pt.), high resistance to pear leaf blister mite (9 pt.).

Signs of identification of the Slavka specimen that determine its difference (morphological, biochemical, etc.): life form – a sprawling tree, crown shape – cup-shaped, a high number of skeletal branches (>10), strong branching, the angle of skeletal branches relative to the trunk is 55° at a height of 1.4 m (Fig. 6).



Figure 6. Plant (tree) of the wild form of Slavka checker tree

Source: photo by the authors

Plants of the above form are also characterised by a large size of the vegetative bud (>8 mm), the position of the vegetative bud relative to the shoot is compressed. The time of the beginning of the development of vegetative buds is average (the end of the 3rd ten days of March – the beginning of the 1st ten days of April), the time of flowering of vegetative buds (the appearance of leaves) is average (2nd ten days of April) and the time of flowering is also average (the beginning of the 2nd ten days of May). Morphological characteristics of the leaf are as follows: the intensity of the green colour

of the leaf is moderate, the size of the leaf is average (11.5×9.9 cm), the leaf type is simple, the shape of the leaf is pointed-ovate lobed, the length of the leaf petiole is medium (4 cm), there is no pubescence on the upper and lower sides, the type of the tip is pointed – stretched, the shape of the base is notched, the shape of the edge is biserrate, the number of blades is 7, the length of the petiole is average (4 cm), the density of placement at the end of the shoot is average (6 units). The time of the beginning of yellow leaf colour is average (late 2nd – early 3rd ten days of September). The time of leaf fall is also average and falls on (3rd ten days of October). Checker trees are characterised by an inflorescence in the form of a corymb of medi-

um size, with a diameter of 20 cm, the flower is average in diameter (d=1.5 cm), the perianth petals are white, intersect, placed horizontally. The number of flowers on the corymb is greater than for Eva and Podolianochka forms, and averages 58. Self-fertilisation for this specimen is high (more than 75%). Next, the study considers the morphological parameters of fruits: diameter – large (2.4 cm), density of the location of lenticels – average, shape – elliptical, or broadly oval, peduncle length – long (5 cm), skin hairiness – present, villi – whitish, colour – light brown, colour of the fruit pulp – brown, seed colour – light chestnut or brown. The fruit is tall (1.8 cm), average in width (1.5-2.2 cm), and the height-to-width ratio is average (Fig. 7).



Figure 7. Leaves and fruits of the wild form of Slavka checker tree

Source: photo by the authors

The tasting score of the fruit is above average or 7 points. The taste of the fruit is moderately sweet with a slight sourness, fruity with hints of dried apricots and raisins. The time of the beginning of fruit ripening is average (1st ten days of September). The average fruit yield at the age of 29 years is more than 15 kg/plant.

Notably, for new forms of checker trees, in addition to morphology, a biochemical analysis of fruits was carried out. It was found that for the forms of Slavka and Podolianochka, fruits in technical ripeness are characterised by an increased content of total sugars and polyphenolic compounds, compared to the Eva form (Table 2).

Table 2. Biochemical properties of fruits of new forms of checker tree

Qualitative parameters of the fruit	Form		
	Eva	Slavka	Podolianochka
Vitamin C, mg/100 g	55.0	38.0	48.0
Sugars (total amount), % of raw weight	8.6	12.43	10.4
Dry matter, % of raw weight	44.3	42.12	42.1
Dry soluble substance, % of raw weight	36.5	12.5	22.5
Titrated organic acids, % of raw weight	1.9	1.8	1.9
Pectin substances, % of raw weight	2.72	0.72	2.54
Polyphenolic compounds, mg/100 g	425.6	711.0	441.0
Flavonoids, mg/100 g of raw weight	6.7	6.9	6.0
Anthocyanins, mg/100 g of raw weight	0.6	0.7	0.7
Chalcones, mg/100 g of raw weight	2.44	2.6	2.17
Tasting score, points (1-9)**	high (8.0)	7.0	8.0
Sugar-acid index (SAI)	5.7	5.8	5.6
Fruit taste	moderately sweet with a slight sourness, fruity with hints of dried apricots	moderately sweet with a slight sourness, fruity with hints of dried apricots and raisins	moderately sweet with a slight sourness, fruity with hints of dried apricots, excellent aftertaste of dried fruits
Transportability, score (1-9)	9	8	8

Source: developed by the authors

Despite certain differences in the indicators of biochemical properties, the fruits of all the studied forms of checker tree have the same SAI and a high tasting score.

In parallel with the study of morphological characteristics of plants and biochemical properties of fruits, their ecological properties, namely, resistance to adverse biotic and abiotic

environmental factors, were investigated (Table 3). According to Table 3, the forms of checker tree are characterised by high resistance to pests, above average and increased winter hardiness, and high drought resistance, which is important in the case of introduction of these forms into the areas of unstable or insufficient moisture in Ukraine.

Table 3. Resistance of new forms of checker tree to adverse biotic and abiotic environmental factors

Factor	Form		
	Eva	Podolianochka	Slavka
pear leaf blister mite (<i>Eriophyes piri</i> Pagenst.), score (1-9)	8	8	9
rowan aphids (<i>Dentatus sorbi</i> Ralt.), score (1-9)	7	7	7
winter hardiness, according to S.Ya. Sokolova, points (1-8)	6 (above average, the top of annual shoots freezes)	6 (above average, the top of annual shoots freezes)	7.5 (the top of annual shoots rarely freezes)
drought resistance, according to S.S. Pyatnitsky, score (1-5)	4.5 (high, leaves lose their turgor during the day, wither, but restore it at night), for young plants – medium, 4 pt.		

Source: developed by the authors

According to the findings, the new forms seemed well adapted to the complex of weather and climatic factors of the northern forest-steppe of Ukraine, in particular, according to the results of overwintering, the average winter hardiness score was 2.5 points. The period of fruit fall. Long-term fruit ripening (1.5 months): beginning – 2nd ten days of August, end – late September. Fruits can remain on the tree until the first frost, and then gradually fall off. It was found that the phenophase of “budding” lasts from April 22 to May 5, and the phenophase of “flowering” takes place from May 8 to May 22. The duration of these phenophases is 18-28 days and depends on the temperature regime.

After the 2018 harvest year, in the following 2019-2021 years of research, checker tree slowly restores the fruiting energy.

For example, the “fruit ripening” phase in 2015 fell on August 5, and full fall ended on August 15, and in 2018, fruit ripening occurred on September 15, and mass fall – on September 28. In checker trees, this period varies by almost a month in different years. Under favourable weather conditions, the ripening period of fruits occurs in the 1st ten days of September; they are juicy and much larger, fall off completely after the first frost.

The average vegetation period is 216 days. The growth period of shoots lasts 143-189 days. Then the plant enters the dormant period, which lasts an average of 150 days.

The analysis and systematisation of the literature revealed that the species of checker tree (*Torminalis glaberrima* (Gand. Sennikov & Kurtto) is a forest, medicinal, fruit plant that belongs to a monotypic genus *Torminalis* Medik., family *Rosaceae*, and until recently its official name was *Sorbus torminalis* (L.) Crantz, first published in 1763 by the German botanist Heinrich Johann Nepomuk von Crantz, and until 2017 belonged to the genus *Sorbus*,

representing the section *Torminaria*. However, based on statements of A. Kurtto *et al.* (2018), species with simple leaves traditionally belong to the genus *Sorbus*, and as noted by E.Y.Y. Lo & M.J. Donoghue (2012) is considered to form a separate monophyletic group.

As noted by Y. Prokopuk *et al.* (2022), checker tree is one of the most valuable hardwoods in Europe, in particular *Torminalis glaberrima*, which has prospects in green landscape construction, including urban forestry, especially in regions with predicted edaphotope moisture deficiency. According to V. Sarv *et al.* (2020), checker tree fruits have a therapeutic effect, as they show high antioxidant activity due to the high content of phenolic and flavonoid compounds, tannins. Therefore, fruits have long been used to treat, including various inflammations, intestinal disorders, etc. According to A. Aytin *et al.* (2018), checker tree wood is fine-grained, very dense and has good flexural strength, it is used for the manufacture of various materials. In particular in the past, such wood was used for the manufacture of screws for wine presses, billiard tables, musical instruments, turning products, flutes, keys for pianos, organs, harpsichords and bagpipes, bases for measuring instruments, etc., since the wood of these plants does not expand or contract.

Based on an in-depth analysis of the theoretical material, L. Lanier *et al.* (1990) note that the range of checker trees covers certain territories of Ukraine (Podillia, Bukovina, Eastern Carpathian Foothills, Transcarpathia, Crimea), and other European countries (Great Britain, France, Italy, Switzerland, Austria, Czech Republic, Slovakia, Denmark, Germany, Poland, Romania, Hungary, Bulgaria, Moldova, Sakartvelo, etc.), in particular, which are located on the territory of the Balkans (Croatia, Montenegro, Bosnia and Herzegovina, North Macedonia, Albania, Greece) and the Pyrenees (Portugal, Spain) peninsulas, and in certain areas of West

Asia (Turkey, Iran, Azerbaijan, Armenia) and North-West Africa (Lebanon, Syria, Morocco, Algeria). Notably, this species was introduced to the territory of the United States of America, Washington state.

Torminalis glaberrima (Gand.) Sennikov & Kurtto includes two varieties: *Torminalis glaberrima* var. *torminalis* (range: Europe, north-western Africa) and *Torminalis glaberrima* var. *caucasica* (mountain ecosystems of the Caucasus and Elbrus). L.V. Markivska *et al.* (2020), quoting E.C. Gabrielyan, notes that in addition to the above-mentioned varieties, according to the degree of dissection of the leaf blade, there are also *Torminalis glaberrima* var. *pinnatifida*. Based on the morphological characteristics of fruits, L.V. Markivska *et al.* (2020), quoting M.I. Kosets, identifies 3 mutational forms, emphasising their ancient origin: *Sorbus torminalis* (L.) Crantz f. *genuiana* Kossetz, *S. torminalis* (L.) Crantz f. *intermedia* Kossetz and *S. torminalis* (L.) Crantz f. *dolichocarpa* Kossetz.

In Ukraine, checker tree is not subject to selective felling and is protected as a rare and valuable native species in the Dniester Canyon and Chernivtsi regional landscape parks, Karmeliukove Podillia and Podilski Tovtry national nature parks (NPP), Crimean, Karadazh, Yalta mountain and forest nature reserves, and Medobory (a protected area within the Pidvolochysk and Husiatyn districts of Ternopil Oblast), and protected areas of Vinnytsia, Ternopil, Ivano-Frankivsk, and Chernivtsi oblasts, have been listed in the Red Book of Ukraine since 2009 with the endangered status. Unlike in Ukraine, in France, the checker tree is not threatened with extinction and the International Union for Conservation of Nature (IUCN) classifies it as a species with a low risk of extinction, but locally it is considered vulnerable, in particular, in the Nord-Pas-de-Calais (former French region). In the forest ecosystems of south-western Germany, on behalf of the Federal Agency for

Agriculture and Food of this country, during 2010–2013, 80 thousand rare species of checker tree were registered, individual specimens, in particular near Blankenheim (North Rhine-Westphalia), acquired the status of natural monuments (Latté, 2021). In Poland, the checker tree has been under strict protection since 1946, is included in the Red List of this country and is almost threatened with extinction and is protected in such reserves as: Czerwona Róża, Brzęki, Białowodzka Góra, Wąwóz Lipa, Ustronie, etc. (Kaźmierczakowa *et al.*, 2016).

L. Willey (2020) reports that only 2% of the UK's territory is occupied by forests, so the preservation of seeds of ancient forest species-indicators, including checker tree (*Torminalis glaberrima*), is crucial.

According to M.C. Rivers & E. Beech (2017) internationally, checker tree is on the Global Red List and in the European Red List of Trees (Rivers) in the category of Least Concern (LC or LR/lc) (Rivers *et al.*, 2019). N.P. Schpak (2019) emphasises the importance of *in vitro* methods in combination with *ex situ* as a means of preserving and maintaining the level of stability of checker tree species.

Checker tree plants are mesomorphic, scleromorphic nanophanerophyte or phanerophyte can often be found in association with oak, beech, ash, hornbeam. Checker tree is distributed in the undergrowth of oak and beech forests, or ecotone between beech and oak forests, and in mountain oak forests. As noted by L.V. Markivska *et al.* (2020) and N.P. Schpak *et al.* (2020), for the renewal of checker trees, the taxation component of plantings includes up to 8 units of oak, 3 – hornbeam, 2 – ash, 1 – related species, including checker tree.

Young checker trees are not demanding for lighting and grow well in partial shade, unlike older plants. The fruit is a food base for many birds and some mammals, which makes the tree ecologically important. M. Kovanda (1992)

notes that the life span of checker tree exceeds 300 years, in particular, 280 and 300-year-old specimens were found in the Czech Republic (the town of Tišnov in the Brno-Venkov district of the South Moravian region and the town of Železná Ruda in the Klatovy district of the Plzeň region). According to Monumentaltrees (n.d.) on the territory of Austria (Brand-Laaben, Neulengbach, in the Vienna forest, as well as on the outskirts of the village of Kropfsdorf near the town of Michelbach, Lower Austria) there are several very tall trees over 25 m.

Checker tree *Torminalis glaberrima* is a deciduous tree up to 25 m (30 m) tall by biomorphology, with a trunk diameter of 15-75 cm (up to 1 m), and a growth rate of about 0.5 m during the growing season. Notably, in Germany, in particular in Hengstberg, east of Gross Lengden in the south of Lower Saxony, checker tree plants, which do not dominate in any forest group and are usually found individually or in groups, are 35 m high. The crown of checker trees is dense, narrow in habitus, and in individual specimens – wide. According to the shape of the top, they range from cone-shaped, semicircular, ovate, inversely ovate, elongated, rounded to opposite elliptical. The root system of plants is buried up to 3 m. Buds are yellow-green, yellow-olive, not pubescent, sticky, very small, small, medium and large in size, round-ovate, round-elongated in shape, and also characterised by different apices: blunt, rounded, and pointed. In addition, vegetative buds at the angle of placement relative to the shoot are very or slightly deviated, pressed. The leaves of plants are green, alternate, simple, about 20 cm long, up to 10 cm wide, palmate-lobed, and the blades at the top are pointed, their number is from 3 to 7. Inflorescence – corymb-shaped. The fruit is an apple up to 15 mm long, with a diameter of about 10 mm, the skin colour is light or dark brown, less often red-brown. According to reports of P.A. Thomas (2017), checker tree is

diploid ($2n=34$) or exclusively triploid ($2n=3x=51$), its plants are characterised by cross-pollination (alogamy), autogamy accounts for only about 1%. Due to cross-pollination, checker trees are characterised by xenogamy or pollination with transferred pollen from one flower to the stigma of the pistil of another flower of a particular plant, which, according to the authors (Moskalets *et al.*, 2020) is close to 75%. By hybridisation, checker tree develops diploid and polyploid hybrids with representatives of the genus *Aria* (Pellicer *et al.*, 2012), in particular, hybrids with mountain ash of the subgenus or genus *Aria* develops forms that belong to the genus *Karpatisorbus*, rowan trees of subgenera (or genera) *Aria* and *Sorbus* – forms belonging to the genus *Scandosorbus* (= *Borkhausenia*), with species of the genus *Malus* – hybrids that are allocated to the genus \times *Torminalis Holub*. According to K.P. Latté (2021) hybridisation between *Torminalis glaberrima* and different species from the genus *Aria* (in particular *Sorbusaria*) gave an opportunity to create species *Sorbus latifolia* and *Sorbus bristoliensis*. In addition, as evidenced by T. Rich *et al.* (2022), checker tree gave rise to numerous taxa in *Sorbus* nothosubgenus *Tormaria* Májovský & Bernátová, and several taxa in *Sorbus* nothosubgenus *Triparens* M. Lepší & T.C.G. Rich, and thus it is an important ancestral species.

In natural conditions, it is possible to select forms of checker tree with valuable economic characteristics that can be effectively used in the conditions of fruit, decorative gardening, forestry (Grynyk *et al.*, 2019). According to C.M. Piagnani *et al.* (2018) and V. Loewe-Muñoz *et al.* (2020) mixed plantings of checker tree with other species allow selecting specimens with the best wood quality.

Summing up the above, it can be noted that increasing the attention of the fruit and berry sector of agriculture and forestry to checker tree, and the search and selection of new ecological and adaptive forms for introduction into

the system of the ecological network has prospects and ecological importance for combining with the biocenotic link, preserving as a Red Book species in Ukraine.

Conclusions

New forms of checker tree – Eva (UN 0700091), Slavka (UN 0700090), and Podolianochka (UN 0700092) – were selected and studied. They were included in the Genetic Bank of Plants of Ukraine in 2022 by the National Centre for Plant Genetic Resources of Ukraine (Kharkiv).

Morphological studies have revealed a weak growth force of checker trees of the Eva, Slavka, and Podolianochka forms. It has been documented that the habitus of Eva is conical, that of Podolianochka – from straight to spreading, and that of Slavka is spreading. In the open area, various crown shapes are noted: in Eva – elongated, in Slavka – rounded, and in Podolianochka – transversely elliptical. New forms have strong branching. For the forms under study, the anthocyanin colour of the top of the young shoot is moderate, and the colour of the annual shoot is dark brown. Regarding vegetative buds, differences are found in the shape of the tip: Eva – pointed, Podolianochka – blunt, Slavka – rounded. The size of vegetative buds varied, but all forms are characterised by their pressing. Morphological differences in the leaves were found to be insignificant: the density of placement, length, width of the leaves – average, green colour – moderate, cross-sectional profile shape – straight or slightly concave, anthocyanin colour – weak or absent.

As for the morphological characteristics of the flower, it was noted that the pedicel is long (1.5–2 mm), the colour of the anther is yellow and orange, the petal shape is rounded, the pistil stigmas are lower than the anther height, i.e., heterostylic or equipetal, which leads to better contact of insects with pollen during nectar collection.

It is worth noting that the new forms of checker trees are not characterised by uniform ripening of elliptical fruits. If the size of the fruit for the Eva and Podolianochka forms is large, then for Slavka it is very large. However, the Slavka form is distinguished by its greater weight and aroma.

It was found that the elements of originality of the Slavka form are a feature of the crown shape (cup-shaped), which determines the level of productivity, low growth force (0.25 m/vegetation), good tolerance of pruning (which affects the size and yield of fruits), increased fruit weight (1.9 g), high number of fruits on the stem (≥ 20), pleasant and harmonious taste of fruits, lack of periodicity in fruiting in nature and in culture, high self-fruitfulness (75%), increased yield of fruits from the plant (> 15 kg/plant), by year (5 t/ha), increased winter hardiness (7.5 pt.), high drought resistance (8 pt.), high resistance to pear leaf blister mite (9 pt.). Elements of originality of the Podolianochka form are the average growth force (0.25 m/vegetation), high degree of flowering (70%), uniform ripening of fruits in culture, high fruit weight (1.8 g), average ripeness group, increased content of ascorbic acid in fruits. It was found out that the elements of originality of the Eva form are high plasticity in terms of pruning, increased fruit weight (2.1 g), large size of fruits (fruit diameter – 2.2 cm), high degree of flowering (60–80%), increased self-fertility (69%), increased content of ascorbic acid (55 mg/100 g of raw weight), high tasting score of fruits (5 pt.), above average winter and increased drought resistance, early time of maximum fruiting in culture (on the 3rd year), increased fruit yield from the plant (12.5 kg).

Further research may be devoted to ensuring the successful survival of selected forms of checker trees in new conditions.

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Conflict of Interest

None.

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Еколого-біологічні особливості відібраних форм береки лікарської для успішної адресної інтродукції та реінтродукції в екомережу України

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Анотація. В статті розглянуто проблематику щодо інтродукції і реінтродукції червонокнижного виду береки лікарської в систему декоративного садівництва та лісозахисних і лісових екосистем. Саме тому метою роботи було провести моніторинг зелених коридорів сільських і міських екосистем лісостепової зони України, дослідити та відібрати кращі за морфологічними ознаками і фізіологічними властивостями форми береки лікарської для перспективних напрямів поширення і збереження у вигляді чистих і мішаних насаджень. У наукових дослідженнях застосовано такі методи: маршрутний, польовий, біометричний, лабораторний, порівняльного аналізу, математично-статистичний. В процесі виконання роботи інтродуковано, вивчено в умовах *in situ* та *ex situ* та відібрано нові форми береки лікарської для перспектив подальшої їх інтродукції та реінтродукції в екомережу України та збереження для активації трофічних, форичних та інших типів біотичних взаємодій в єдиній територіальній екосистемі. У зоні зелених коридорів сільських і міських екосистем лісостепової зони України виявлено малопоширені біотиби *Torminalis glaberrima* (Gand.)

Sennikov & Kurtto f. *Intermedia* Kossetz. Деякі екземпляри цих біотипів визначено як цінний матеріал для введення в систему плодового і декоративного садівництва, включаючи парки-пам'ятки садово-паркового мистецтва, а також пам'ятники природи, заповідні урочища, заказники і заповідники чистих і мішаних насаджень, алеї, лісомеліоративні смуги, тощо. Встановлено, що елементами новизни відібраних форм береки лікарської Єва, Подоляночка і Славка є особливість форми крони, яка визначає рівень продуктивності, мала і середня сила росту, нормальна реакція на формуючу обрізку (що впливає на крупність і урожайність плодів), висока ступінь цвітіння (60-80 %), крупноплідність (діаметр плоду понад 2 см), підвищена маса плоду (1,8-2,1 г), висока кількість плодів на суплідді (≥ 20 шт.), приємно-гармонійний смак плодів, висока якість плодів, відсутність періодичності в плодоношенні в природі і в культурі, висока ксеногамія (69-75 %), висока урожайність плодів з рослини, підвищена зимостійкість (7,5 б.), висока посухостійкість (8 б.) і стійкість до шкідників, у т. ч. грушевого кліщика (7-9 б.). Результати досліджень можуть бути використані в перспективі поповнення чистих і мішаних насаджень екологічної мережі України

Ключові слова: *Torminalis glaberrima* (Gand.) Sennikov & Kurttof. *Intermedia* Kossetz.; біохімічні властивості; нові біотипи; поповнення екологічної мережі; червонокнижний вид; вміст аскорбінової кислоти